DOCUMENT RESUME

ED 284 423 FL 016 688

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TITLE Listening and Speaking: A Cybernetic Synthesis.
PUB DATE Nov 85
NOTE 31p.
PUB TYPE Reports - Evaluative/Feasibility (142) -- Journal Articles (080)
JOURNAL CIT Nagoya University of Commerce Bulletin; v30 p697-725 Nov 1985

EDRS PRICE MF01/PC02 Plus Postage.
DESCRIPTORS *Cognitive Processes; *Cybernetics; *Feedback; Language Processing; *Learning Theories; Listening Comprehension; *Listening Skills; Second Language Learning; *Speech Communication; Student Centered Curriculum; Teacher Role

ABSTRACT

Cybernetic feedback theory sees the individual as a self-organizing feedback control system that generates its own activity to control its own perceptions. Applying the principle of feedback to language use, it appears that speaking as an overt public behavior is controlled by an internally private listening capacity. With that listening capacity, the transfer to speaking is greatly enhanced, though not automatic, and without the listening capacity, spontaneous speech, internally generated, does not occur. Previous approaches had had the language teacher push the student toward speech, with the teacher in control of the environment that controls the student's behavior. The cybernetic approach has the internal language structure pulling out the performance (speech) based on built-in expectations within the language structure learned through listening guidance. The student does this when he feels ready. He is in control of his own behavior. The teacher does not correct speech errors directly but notes them for further training in careful listening. In this approach, the teacher's task is to enhance the student's perceptual capacity. This technique could revolutionize foreign language teaching. (Author/MSE)

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LISTENING AND SPEAKING
A CYBERNETIC SYNTHESIS

James R. Nord

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栗本学園創立五十周年記念
名古屋商科大学論集
第30巻（1, 2合併号）
昭和60年11月発行　抜　刷

FL 016 688

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James R. Nord

Introduction

600 years ago, Copernicus helped change the world we live in by proposing that astronomers change their viewpoint. 500 years ago, Columbus also changed the world by following his "new vision" of the world. Both of these change of viewpoints, were resisted by many people, and it took a long time for a majority of people to accept the new viewpoints. Both viewpoints are basically contrary to "common sense". Even today, many people still linguistically refer to the sun revolving around the earth with expressions such as "sunrise" and "sunset". Many people will still refer to "upstairs" and "downstairs" as if we lived in a flat world of ups and downs, instead of referring to the more accurate description of "outstairs" and "instairs". It is therefore understandable that many in the language teaching profession are still not sure about the exact role of listening and speaking in the practice of language teaching.

When major shifts of viewpoint occur in the sciences, there is also a period of resistance, slow acceptance, and often a verbal habit pattern which persists for many years. Kuhn (1962) has articulated a theory of intellectual change that has had significant impact on the history of science. According to Kuhn, once scientific communities have reached a certain level of maturity, they begin to operate on the basis of "some implicit body of intertwined theoretical and methodological belief" that he calls a para-

digm. (p.5) When difficulties arise in using the paradigm, when an extraordinary set of investigations begins which leads to a new set of commitments, to a new world view, to a new paradigm, a "scientific revolution" is taking place.

Only 40 years ago, a scientific revolution began which has created ripple effects throughout the various scientific disciplines. Because it is relatively new, it is not well known, somewhat resisted, and generally not applied at the professional level. Yet, it is precisely at the professional level that this new scientific position will ultimately have its greatest impact. Previously, science has focused upon knowledge. That is, they have tried to abstract events until they approached a timeless state. $E = MC2$ is one of the highest achievements of the physical sciences. It is however a mathematical formula. It is therefore reversible. The one way arrow of time has been eliminated from physical sciences mathematical formulation of events.

The new scientific approach works in the opposite direction. It focuses upon events as they take place with the irreversible movement of time. This approach studies structures as they are effected by events which take place over time. They are not reversible. The "scientific revolution" returns time back into the formula. It therefore deals more directly with the concerns of the professional. If understood therefore, it could have profound implications for the basic practices of foreign language teaching. It strongly supports the listening approach and significantly changes the way speaking is understood. It is however, somewhat contrary to "common sense" and therefore requires a more extensive explanation. This paper attempts to provide a introduction to this "scientific revolution" and a few of its implications for foreign language teaching and future research.

Current Language Teaching Controversy

Twenty years ago, listening was largely ignored as a language skill

to be taught. The focus of the then current "audio-lingual" methodology was on speaking. Many believed that listening would "automatically" occur in the process of learning to speak. Most felt that listening was somehow the easiest of the four skills and was learned largely by exposure. Some even believed that practice in speaking was the best way to learn to listen. Fries (1945) for example, after recognizing the two phases of "oral production" and "receptive understanding" states, "As a matter of fact, practice in production is one of the best means of developing recognition." (p.8) Others however disputed this point. Belasco (1971) writes that he was, "jolted by the realization that it is possible to develop so-called 'speaking' ability (vocalizing) and *yet be virtually incompetent* in understanding the spoken language." (p.195)

Partly as a consequence of this kind of discovery, and partly as a consequence of research by a group somewhat outside the language establishment, a shift of attention was signaled. Over the past ten to fifteen years, listening comprehension has been promoted from a somewhat neglected skill to a status of crucial importance in language learning, especially though not exclusively in the United States. Part of the shift has been due to researchers such as Asher (1966, 1969, 1972, 1977), Gary (1975, 1980), Nord (1975, 1980), Postovsky (1970, 1974) and Winitz & Reed (1973, 1975). All of these researchers focused upon listening as the focal skill and all of these researchers advocated a delay of oral response demand. All pointed out that listening was both the necessary and sufficient causal factor in language learning and that speaking should not be forced. Krashen (1982) has made the point most clearly when he stated, "if you want to teach someone to talk, do not teach them to talk, give them comprehensible input!" (p.21)

This position seemed so extreme that even those who felt that listening deserved more attention were horrified. Wilga Rivers for example, was one of those who had advocated more emphasis on listening quite early on (Rivers, 1966), but who has since turned to attack the position quite

vehemently (Rivers, 1984). While some criticism of some specific attempts to apply the new paradigm to language teaching may be justified, it seems premature to judge so harshly on only a few examples, and to throw the baby out with the bathwater. The new viewpoint is only 40 years old. It needs refining yes. It needs to be understood better even by its advocates yes. But it also needs to be better understood by its critiques before their criticism can be considered valid. Otherwise it begins to sound like many of the critiques of Copernicus and Columbus who merely held back progress for many years.

The new approach certainly does seems contrary to "common sense". Most of the opponents to the comprehension approach have argued that "we learn by doing". We learn to swim by swimming and we learn to play the piano by playing not by listening to someone else play. Their argument therefore is that speaking is a skill which must be taught if it is to be learned. The argument has a ring of authenticity to the ears of the ordinary language teacher. Many of the opponents to the extreme comprehension position do advocate communicative competence as a focus of attention today. Their theme song is "interaction" in which both listening and speaking are practiced from the first day. Their position on listening is that listening is important, but students should be listening to "authentic" materials and then responding orally to it. Scientifically, these people seem either unawareof, or indifferent to the "scientific revolution" which has taken place in the philosophy of science itself.

The Scientific Controversy over Causality

In the philosophy of science, a keystone of scientific explanation has been *causality*. Von Foerster (1972) has pointed out that one of the basic pillars of the scientific method is the "principle of the necessary and sufficient cause." He points out that this basic principle also implies that almost everything else in the universe shall be considered irrelevant. "If P

are the causes that are to explain the perceived effect Q, then the principle of necessary and sufficient cause forces us to reduce our perception of effects further and further until we hit upon the necessary and sufficient cause that produces the desired effect: everything else in the universe shall be irrelevant." (p.37) He goes on to point out that such a position is counter-productive in attempting to understand any evolutionary process such as the growth of an individual, the development of a society, or . . . the learning process. He then points out that Aristotle many years earlier had referred to two major types of causes which were the center of controversy within the philosophy of science for many years. Aristotle distinguished between two kinds of causes, one, the "efficient cause" which pushes from behind, the other the "final cause" which beckons from ahead. These two causal explanations were part of the early days of science and they provided distinctly different explanatory frameworks for either innate matter or living organisms. The distinction was primarily that "efficient causes" temporally *precedes* the effect, while the "final cause" *succeeds* its effect in time. For example, when striking a match on the treated surface of a match box, the striking is the (efficient) cause for the match to ignite. However, the (final) cause is my wish to see it ignited.

The scientific community of the 17th and 18th centuries argued about these two causal factors. The physical sciences were the leading proponents of the *analytic method.* The analytic method is basically the examination of the relationship between pairs of variables at a time and the construction of a mathematical theory in which (efficient) causally interrelated factors were combined into a single equation. Attempts to extend the analytic method to the study of living processes were only partially successful. According to one view, called vitalism, the extension of the analytic method to living processes was in principle impossible, because the living processes were not governed by the same laws as non-living processes. One position firmly defended by the vitalists was that living beings were governed by goals and purposes, while inanimate objects which

obeyed the laws of physics were not goal oriented. Vitalists, using the concept of final causes which pull from ahead, or teleological explanations, were closely associated with a belief in God.

Using the "If such and so (condition) . . . then this result" paradigm, the science of physics developed more and more mechanical explanations of motion without reference to its possible future states. The success of the mechanical view of subsuming a vast variety of motions under a single theory plus the tainted association of the vitalists with religion, contributed to the demise of teleological explanations in physics. By the beginning of the twentieth century, the scientific community as a whole, regardless of specific discipline, rejected teleological explanations as "unscientific". The universe was seen as a giant mechanical clockwork in which science had simply to continue the analysis to "understand" the entire universe. It was in this atmosphere that modern "scientific" psychology and linguistics grew up. As Rapoport (1968) expressed it,

> With the advent of the analytic method in the physical sciences, the system point of view (with its heavy reliance on directly perceived analogies and teleological explanations) receded into the background. Sophisticated biology eschewed teleological explanations. Empirically oriented social scientists abandoned social philosophy in favor of strictly circumscribed investigations in the best traditions of controlled experiment, where one variable is "pitted" against another without reference to how the relationship obtained can be fitted into a "picture". Scientific psychology turned away from its original subject matter, the psyche, toward piecemeal investigations in thoroughly "sterilized" settings. (p. xxi)

In linguistics, the subject matter became the publicly observable data, often "sterilized" from its meaning, and completely divorced from the temporal variable. In psychology, the behavioral movement vigorously opposed all teleological explanations of behavior and insisted that only

observable stimuli (efficient causes) and observable responses (effects) were legitimate explanatory factors for a "scientific psychology". As Bandura (1977) put it,

> Developments in behavioral theory shifted the focus of causal explanation from amorphous internal determinants to detailed examination of external influences on human responsiveness. Behavior has been extensively analyzed in terms of the stimulus conditions that evoke it and the reinforcing conditions that maintain it . . . Results of such investigations have led many psychologists to view the determinants of behavior as residing not within the organism, but in the environment. (p.5)

It is from this "scientific" background that most of the present day teachers have been influenced. The linguistic sciences have provided them with a static abstract language schemata external to the brain, while the behavioral psychologists have focused their attention upon the observable responses such as speaking. It is therefore quite understandable how a "radical" approach such as the comprehension approach can be viewed with some skepticism and requires greater explanation. The new approach essentially says that speaking is (final) "caused" by listening to oneself speak. From this viewpoint, it becomes very important that listening is well taught, because speaking will develop naturally from it through feedback.

Shifting the Paradigm

The publication of Wiener's book Cybernetics in 1948 signalled a return to the systems approach and teleological causality as a legitimate explanatory framework within the sciences. Wiener (1948) proposed that systems can self-regulate themselves on the basis of their outputs, rather than their inputs. To put it another way, they can be controlled on the

basis of final cause as well as efficient cause. The pull of goal seeking became as legitimate a scientific explanation as the push of the efficient causal connection. Central to this new explanatory legitimacy is a concept knowns as feedback. Wiener (1954) pointed out that feedback operates in both animal and machine systems.

> This control of a machine on the basis of its *actual* performance rather than its *expected* performance is known as *feedback*, and involves sensory members which are actuated by motor members and perform the function of *tell-tales* or *monitors* – of elements which indicate a performance . . .
>
> Something very similar to this occurs in human action. If I pick up my cigar, I do not will to move any specific muscles. Indeed, in many cases, I do not know what those muscles are. What I do is to turn into action a certain feedback mechanism; namely, a reflex in which the amount by which I have yet failed to pick up the cigar is turned into a new and increased order to the lagging muscles, whichever they may be. In this same way, a fairly uniform voluntary command will enable the same task to be performed from widely varying initial positions, and irrespective of the decrease of contraction due to fatique of the muscles . . .
>
> It is my thesis that the operation of the living individual and the operation of some of the newer communication machines are precisely parallel. Both of them have sensory receptors as one stage in their cycle of operation: that is, in both of them, there exists a special apparatus for collecting information from the outer world at low energy levels, and for making it available in the operation of the individual or of the machine. In both cases these external messages are not taken *neat*, but through the internal transforming powers of the apparatus, whether it be alive or dead. The information is then turned into a new form available for the further stages

of performance. In both the animal and the machine this performance is made to be effective on the outer world. In both of them, their *performed* action on the outer world, and not merely their *intended* action, is reported back to the central regulatory apparatus. (p.12-15)

Cybernetic feedback theory is relatively new and hence not thoroughly known even by many in the scientific disciplines. It is barely forty years old. Nevertheless, it has been having profound effects upon much of the scientific community where it has been understood, and once understood should also have a profound effect upon the foreign language teaching community. Two early papers, the first by Ashby (1940) coming from England and the second by Rosenblueth, Wiener and Bigelow (1943) coming from America, first stated the fundamental ideas of cybernetics in a general enough manner that they could be applied to a wide range of scientific problems. Prior to that time, since Maxwell in 1868, the concept was known but restricted to engineering.

In the first paper, Ashby did not use the term "feedback" but he basically described the concept. He illustrated it with a typical negative feedback instrument, a thermostat, that is, a temperature control for an incubator. In the paper by Rosenblueth, Wiener and Bigelow, the concept of negative feedback was explicitly introduced and its importance to purposeful behavior in organisms was stated. They developed a new taxonomy of behavior which has more and more become the foundation for modern behavioral understanding, and which is the basis for the newer understanding of speaking by advocates of the comprehension approach to foreign language teaching.

These cybernetic scientists began by first distinguishing between active and passive behaviors. They defined passive behavior as that behavior which is caused by energy from outside the system. For example, a billiard ball will remain at rest until an outside force "causes" it to move, and then

it will follow a certain trajectory. The energy came from outside the ball, and it follows the laws of motion as set out by Newton. Active behaviors, on the other hand, are defined by these scientists as those in which the system in motion is the source of the energy. For example, they would include the actions of a homing torpedo which has its own energy supply as active behavior. According to this definition, almost all animal behavior including human behavior is active behavior. An exception might be the movement of a cat if it is thrown, or the falling of a boxer after he has been hit. In these cases, the behavior would be considered passive and follow the laws of physics. Physics, in fact, can be considered the study of passive behavior. Efficient causal factors operate in passive behavior. Their role in active behavior is more complex.

Active behavior, which all humans exhibit was then divided into two sub categories: random and purposeful. A drunk walking around and bumping into a lamp post is often described as exhibiting random behavior. This is because there is no way to predict its sequence. Purposeful behavior is predictable behavior. It generally is considered to either involve a goal and the movement to that goal, or it involves a series of motions based upon a set of rules which will allow one to predict the next movement. The distinction is not quite however as straightforward as it may seem. What appears to be random behavior and unpredictable to someone who does not know the goal being pursued, or the rules being followed, may turn out to be highly predictable and hence purposeful, once this is known to the observer. To be able to make the shift from random to purposeful, often simply requires the ability to shift one's point of view, to observe the complementary side of the behavior. For example, observing someone driving up a mountain road and looking only at the motion of the steering wheel, might lead one to conclude that this is random behavior. But if one observed the distance between the edge of the tire and the edge of the road, one would be able to notice a great consistency and hence imply purpose and predictability to this behavior. The ability to shift points

of view is important in understanding how speaking is active purposeful behavior . . . based on listening.

The cybernetic scientists go on to further subdivide active purposeful behavior into two more categories: (1) open-looped or programmed behavior and (2) closed loop, or feedback behavior. Active purposeful programmed behavior is that behavior in which both all of the energy and all of the information controlling the system are internal to the system. Clockworks were the first major mechanical device to exhibit this type of behavior. Mechanical toys which are designed to exhibit a certain set of behaviors such as toy dogs which walk and bark are in this category. They are run by electric batteries and are controlled by internal mechanical devices. Some of the early electronic robots also exhibited this type of behavior althought most of the modern ones contain feedback control systems as well.

Humans also seem to exhibit some programmed behavior. Sometimes our basic habits seem to be of this nature, when we simply repeat an action without thinking about it and without regard for the effect on the outside world. We often memorize poems in this way, each word seemingly triggering the next word in a chain-like reaction. Rote memory seems to be a kind of programmed behavioral set. Much of the early "Audio-lingual" methodology seemed to involve this type of behavior training. Students could repeat sentence patterns, often not knowing what they meant, or why they were being said, but just producing the sounds one after the other in an active predictable programmed manner. Humans seem to exhibit programmed behavior . . . and they do, sometimes, in certain ways, but a more detailed understanding of that process will come later.

Closed-loop feedback controlled behavior seems to be by far the most common form of human behavior control. This applies to language behavior including both listening and speaking, but the details of that must await a clearer understanding of the general concept. When a cat chases a mouse, he does not set a program into motion, because the mouse will

try to get away, that is, the mouse will try evasive tactics. In other words, as soon as a cat begins to chase a mouse, the cat's environment changes, and he must change his behavior in response to that change. Closed-loop feedback control takes in information from its environment and uses that information to help control its next action. With the cat and the mouse, the action and the feedback are so quick we often don't recognize its presence. The process also requires predictions about the future movements of the mouse as well as feedback on whether that which was predicted (guessed) actually happened.

In criticizing the former behavioral position, Powers (1973b) points out that "Behaviorists have not distinguished between *means* and *ends* between *acts* and *results* – because they have not used the model that is appropriate to behavior." (p.351) Traditional psychology employs the open-loop concept of cause and effect in behavior; the effect (behavior) depends on the cause (stimulus) but not vice versa. The closed loop concept treats behavior as one of the causes of that same behavior. That is, we often behave in order to receive the stimuli we want. Or as Powers (1973a) put it, "What an organism senses affects what it does, *and what it does affects what it senses.*" (p.41) To behave is to control one's own perceptions.

Traditional psychology saw the "results" of the behavior of a subject from their point of view, but ignored both the motor acts, and the perceptions of the subject. When a pigeon is trained to walk in a figure eight pattern, there are at least two levels at which it must be viewed. The first is what the behaviorists . . . and teachers tend to observe – the results, the pattern as observed in the perceptual organs of the experimenter . . . or teacher. But the behavior itself consists of muscular movements themselves. The figure eight is created by walking movements. The act of walking produces the result of a figure eight pattern in the observers perception. The observer sees consistent behavior that remains the same. But the observer fails to notice that the movements are always different. As the pigeon traces out the figure eight over and over, its feet are placed differently on

each repeat of the same point in the pattern. Variable acts produce a constant result.

The result is what the experimental observer sees – and the result – in the mind of the performer is in cybernetic terms, the cause of the movements which create it. The acts of the performer vary in order to create not a consistent behavioral act, but a constant perceptual result. This implies purpose, even on the part of the pigeon. The purpose of behavioral acts are, in cybernetic terms, to produce the perceptual results that are in fact observed. The behavioral experimenter . . . or teacher does not teach behavior. What is learned is a perceptual result which then controls the behavior which produces it. The successful behavioral act is merely an indicator that the perceptual results desired, have been successfully learned. From the cybernetic feedback point of view, the teacher or experimenter can never control the behavior of another. Each individual always controls his own behavioral acts. As Smith and Smith, (1965) put it, "Cybernetic theory views the individual as a feedback system which generates its own activity in order to detect and control specific stimulus characteristics of the environment.": (p.vii)

Cybernetic Feedback Theory with its new taxonomy of behavior began to make ripples in a number of scientific disciplines. It is creating in Kuhn (1962) terms, a "scientific revolution." It has upset the focus on the "analytic" method, and introduced the "synthetic approach" (Ackoff, 1980). The unnecessary narrowing of the scientific approach to the "analytic method" had its advantages, particularly for understanding "passive behavior", but it also had its costs. The advantage was its efficiency. An experimenter may not be right, but he knew what he was looking for. If he didn't find it on the first try, he could modify the hypothesis and try again. This was certainly preferable to attempting to simply catalog anything that one came across, especially since one is likely to come across a great deal. The cost of using a narrow paradigm in science is the cost of using any model. They can serve as blinders instead of as an aid to vision.

As Miller and Starr (1967) expressed it,

> . . . there is a *converse* to this advantage of models which also deserves emphasis. That is that too great use of any one model is likely to lead to the confusion of the model with reality. A microscope is an excellent device for looking at bacteria, but useless for seeing stars. A telescope is fine for the stars but not suitable for seeing bacteria. And neither is any good for reading books. (p.152)

Maslow (1969) expressed it another way, "If the only tool you have is a hammer, you tend to treat everything as if it were a nail." As long as scientists and teachers had to rely on observables in language, speaking was obviously the focus of language research as well as language teaching. With the new conceptual tool of cybernetic feedback control, teleological explanation were legitimatized and active purposeful behaviors such as language usage and speaking could be understood in terms other than S-R connectivist theory. With the new taxonomy of behaviors, listening could be finally investigated as an "active" behavior rather than as a passive one. It could also be seen as the "cause" of speech.

Applying Cybernetic Principles to Understand Speaking

What is speaking and how is it seen from a cybernetic point of view? *Speaking* can be conceived of as a biological action which produces an acoustical time-series we call *speech*. Numerous biological systems are involved in this action, but it is possible to think of them collectively as a single large bio-acoustical system which produces a series of sound units sometimes known as phonemes. The phonemes are ordered, organized and distributed over a time sequence. As listeners we recognize them ordinarily as speech. The speaking system is complex and must be controlled and coordinated by some central agency. That control system we normally refer to as the brain. But how does the brain control the speaking system?

Grant Fairbanks (1954) seems to have been the first person to explicitly apply the cybernetic principles of feedback control to language and human speech production. He created a basic feedback control model in which he pointed out that "auditory monitoring" of one's own speech is not just an ancillary listening function, but rather an integral part of the speech control system. He proposed a model of speech as a servomechanism in which the speech is controlled through feedback loops. Fairbank's insights into the application of cybernetic principles so early after Wiener's published account, show his vision to be truly prophetic. He was however, apparently too far ahead of his contemporaries. His experiments with delayed auditory feedback (Fairbanks, 1955) provided dramatic evidence and did create some discussion. The monitor model presented by Krashen (1977) is in fact derived from discussions about delayed auditory feedback experiments. Unfortunately, various ramifications of cybernetic principles themselves have not been followed up and studied by people within the language field and have therefore not been fully understood by most members of the profession.

The task of exploring the effects of applying cybernetic principles to human behavior fell primarily to people outside the field of language. In a way, this is both predictable, and regretable. Motor behavior is a relatively simple act, which can be examined relatively straight forwardly. Language performance on the other hand involves a much larger portion of "symbolic manipulation" prior to the public response portion of the language performance. Hence it is more complex and more difficult to study. Nevertheless, it is one of the most common human behaviors we know. To understand language as a form of symbolic behavior from a cybernetic point of view would be a major step forward for understanding human behavior in general. Regardless, the other disciplines have provided some solid stepping stones for language people to learn from.

A hierarchial aspect of the feedback model was introduced to the field of psychology by a neurologist, Pribram and a Psychologist, Miller.

(Miller, et al 1960). The model they introduced was call TOTE which stood for *Test, Operate, Test, Exit.* It used the Test as a feedback sensor which compared the actual performance with an intended performance. For example, if one is hammering a nail, one first checks to see if it is still sticking out, then one Operates, or hammers the nail, then one Tests to see if it is still sticking out, or flush. If the Test indicates it is still sticking out, then one Operates, or hammers the nail until it is flush, and then one Exits to another behavior or another nail. What the authors pointed out however, was that the Operation phase was not quite so simple. The Operate phase itself contained a TOTE. For example, within the operation "hammer", one must first Test whether the hammer is up or down. If down, then the Operate must be to raise or lift the head of the hammer. If up, then the Operate must be to lower or hit the nail with the hammer. But one can go even further. Within the operation "lift" there must also be a TOTE regarding the state of the various muscles involved. It must Test whether they are relaxed, tensed, etc.

The hierarchial TOTE model pointed to two major factors. One was that in a hierarchy of feedback loops, some of the Test units could be focused upon the environment external to the total system, i.e. the person looking at the nail, but some of them, while external to the immediate Operate system, were in fact inside the skin of the total system. In terms of the speech system what is being indicated is that feedback loops exist not only through the ear, but also through proprioceptive senses and even within the brain itself. The second factor which became apparent through the model was that time scales are not the same at all levels. The amount of time it takes to adjust one's muscles must be much more rapid than the time it takes to look at the nail. In language training, rate of processing has generally been ignored as a factor, while a cybernetic approach would put it in a central position. It was up to the physiologists to examine this factor more completely.

Welford (1974) has pointed out some of the significance of includ-

ing reaction time as a critical factor in understanding behavior from a cybernetic point of view.

> The fact that it takes time to react has two consequences which are not fully recognized as they deserve to be. First, in any developing situation, there must be some prediction of the trend of events because, if action is to be appropriate at the time it becomes effective, it must have been decided before the events it is designed to meet have occurred. Second, any action taken must be ballistic in the sense that an appreciable time must elapse before it can be modified by any fresh information or feedback from the action itself. (p.382)

A baseball player who is highly skilled at bat, is just as subject to the law of reaction time as anyone. As a batter views the ball coming, he must make a prediction about its continued movement before he begins to move his bat. Once the bat is in motion, the movement continues even thought he may see the ball dropping off and curving away from the position he predicted only a fraction of a second earlier. There is not sufficient time to change the movement of the bat and the called strike only reconfirms the consequence of reaction time. Welford indicates that both the principle of prediction and that of ballistic continuity have far reaching implications.

> Prediction means that action cannot depend on any simple connection between stimulus and response, but must involve a more or less complex computation. To the extent that this is so, the stimulus-response and conditioned reflex approaches to performance are inadequate. The ballistic principle means that elementary units of action, if one may so speak legitimately, are essentially timed and phrases sequences of muscular contractions and relaxations which are initiated as wholes. (p.382)

The prediction referred to by Welford is similar to the "end," or

"result" referred to by Powers earlier. The ballistic principle is similar to Power's "means" or "act". The prediction portions involves a more or less complex computation of anticipated or expected events based upon prior learning. As Bandura (1977) has pointed out, "There are certain regularities in the succession or coexistence of most environmental events. Such uniformities create expectation about what leads to what. Knowledge of conditional relations thus enables one to predict with varying accuracy what is likely to happen under given antecedent conditions." (p.58) The brain is a very good statistical machine. It even works for languages. But as Bandura points out, it develops language expectancies not through just frequency counts, but through the abstracting of rules based upon that statistical analysis. "Rather than simply copying individual utterances, children learn sets of rules which enable them to generate an almost infinite variety of new sentences that they have never heard. It is abstract modeling, with its perceptual, cognitive, and reproductive component processes, rather than simple verbal mimicry, that is most germane to the development of generative grammer." (p.174) He then goes on to point out that, "During initial language learning . . . they can acquire linguistic rules without engaging in any motor speech." (p.174)

The ballistic principle is also a type of computational process. It involves a whole unit of movement. It is a type of "programmed" behavior. In playing tennis, the unit is the whole stroke involving both the drawing back and the driving forward of the racquet. In playing a musical instrument, the unit is not the single note, but the unit consists of the phrase or arpeggio. In language usage, the ballistic unit is the "thought unit", the phrase, which is generally about 3 seconds in length (Turner and Poppel, 1983, p.296) not the word or the phoneme. In these and similar cases, a complex computation is involved based not only upon the immediate stimulus to action, but also future goals, past experiences and concurrent factors such as posture at the moment of action. Welford points out that although the repeated musical phrase, or particular tennis stroke is in one

sense the same as those executed previously, in another sense, it is never the same. This was the conclusion of Bartlett (1932) when in talking about the stroke of an athlete in a skilled athletic game, he observed,

> We may fancy that we are repeating a series of movements learned a long time before from a textbook or from a teacher. But motion study shows that in fact we build afresh on a basis of the immediately preceding balance of postures and momentary needs of the game. Every time we make it, it has its own characteristics. (p.204)

In speaking, we generate a new sound which has its own unique characteristic depending upon the linguistic context, our emotional set, the audience etc, everytime we talk, even though we may be reciting the same phrase we have said a dozen times before. The controlling feature for both the ballistic computation and the prediction computation is feedback. The ballistic computation takes into account feedback from both peripheral senses such as eyes and touch, and from proprioceptive senses within the muscular structure. They operate at different speeds and they are therefore TOTE type computations. The predictions computations take place even faster . . . in the cerebral cortex itself. There is then feedback loops between the ballistic consequences and the predictions computed. Most of these feedback loops act much faster than our conscious understanding of them, which is one of the reasons we tend to ignore them.

Welford proceeds to analyze the consequences of the two principles of prediction and elementary units of actions with respect to time. Using experimental research data from tracking experiments, he pointed out that corrections made in tracking were not continuous, but rather " . . . corrections were intermittent, as if the subject observed an error, made a correction for it, observed again, made a further correction, and so on." (p.383) If, for example, a signal to react has been given, and during the reaction time to it a further signal appears, response to the second signal is delayed

by an amount which suggests that the central processes required to deal with it did not begin until the reaction time to the previous signal had ended. Seemingly, monitoring the response occupies the central mechanism to an extent that precludes their dealing with fresh signals for action until the monitoring is finished. Serial action such as in tracking or in speaking, appears to involve an alternation between, on the one hand, the observing of signals, and computing of responses to them, and on the other hand, monitoring the response made. In other words, "... the speed of serial action does not depend upon the time taken to execute movements, but upon the time required to decide and monitor them." (p.384)

Nuttin and Greenwald (1968) have made a distinction similar to that made by Welford between prediction and ballistic, and Powers between results and acts or ends and means.

> Another distinction that seems warranted is to separate the performance process into two phases, a preparatory phase and an executive phase, the latter of which corresponds to overt behavior ... Corresponding to the preparatory-executive distinction, one may distinguish two categories of learned content: expectations (knowledge of 'what leads to what') and behavioral skills. In effect, it is one thing to learn how to walk – a behavioral skill – and quite another to know how to get from the room one is in to the exit of a building – a set of expectations about relations among environmental events, that is, a cognitive map... The acquisition of expectations may be described as cognitive learning. Expectations can be formalized as structures containing information about what will happen as a result of a given action operating on a given inital situation (p.127)

Applying this analysis to the language using process, we can recognize that the prediction or preparatory phase of speech behavior is the internal generation of the phoneme time-series to be generated. These are then

held in a Test point for monitoring the executive or Operate stage of the performance cycle. "In other words, a representation of the sound being spoken must be made available to the perceptual centers for comparison with the auditory signal that is produced during the articulation of the intended message. If the two match, then the perceptual representation of the auditory signal remains constant and stable." (Lackner, 1974, p.901) If they do not match as in the delay of auditory feedback experiments, then there occurs a" . . . slowing of speech rate, increased loudness of speaking, elevation of pitch of the voice, and a blocking of the normal flow of words that result in artificial stutter. Many errors of articulation appear, including omissions, additions, and substitutions of syllables or words." (Smith & Smith, 1965, p.400). In simple terms we speak what we expect to hear. The ability to hear, to know what to listen for, then comes first. The building of the cognitive map of expectations is what the comprehension approach is focused on. The speaking will be controlled through a feedback loop process.

The prediction computation in language without a motor response is what we could call "thinking" in the language. The prediction computation is also critical in the process of listening, since we do not just listen "passively", but actually generate (predict) what will be heard and then monitor what is heard to compare it to what was expected. Learning to listen then reduces to essentially leaning the predictive computation rules. It is however at this point that the cybernetic models for motor behavior are somewhat over simplified. While they are correct as far as they go, they can not adequately handle the complexity of symbolic prediction. A full coverage of cybernetic understanding of symbolic behavior is beyond the scope of this paper, but a brief sketch will illustrate the principle aspects.

There are basically two aspects of language, the form and the meaning. There are therefore three sets of computations which are necessary to generate the prediction or what is to be heard portion of the perfor-

mance. We now have evidence that these computatiosn take place in different parts of the brain. The first set is the semantic associations. From the general context of the situation, certain semantic associations are generated in thinking. That is, certain expectancies of a meaningfulness nature are generated. There is some evidence that this takes place primarily in the frontal lobes of the brain. (Luria, 1973, p.318) A second set of computations is the symbolic encapsulation of these meanings into the associated word or form in the particular language being used. These computations apparently take place in the "listening" portion of the brain. "If the word is to be spoken, the pattern is transmitted from Wernicke's area to Broca's area where the articulatory form is aroused and passed on to the motor area that controls the movement of the muscles of speech." (Geschwind, 1972, p.79) The computation of the form structure, that is, the expectations regarding sequencing of the words and the function words . . . this we generally refer to as the grammatical rules and it takes place separately. "There thus appears to be a natural neurological separation between the functions of processing sentence form and that of processing semantic representations. This evidence can be taken as an encouraging sign that it is possible to connect cognitive and neurological organization in the domain of language." (Zurif, 1980 p.311)

Critiques of the comprehension approach point out that listening is primarily a semantic activity and that one can listen and understand without really knowing the syntactic or form rules, but these they point out are crucial in speaking. These are redundant systems, and one could learn just the "semantic" rules and "appear" to be a good listener. The lack of syntactic computational rules would perhaps not show up until one tried to speak.

While this fact has been used as an argument that speech is necessary for the syntactical organization to be learned, the element of rate processing does not seem to be taken into account sufficiently. The feedback process from the peripheral organs and from the proprioceptors is of a different

time scale from that of the feedback loop within the cerebral cortex. The semantic and syntactical computations must be coordinated through feedback at this cortical time scale, or it will not be fast enough to control the rest of the system. While speaking practice may help focus the listener's attention on certain critical syntactic points in later listening, the speaking itself does not enhance the learning of these syntactic points directly. This must be done at a rate processing level only available in listening.

Osgood (1957) proposed a three level model, which could account for the different feedback time scales necessary to operate fluent speech.

> The three levels of organization are assumed to apply to both sides of the behavioral equation, to both decoding and encoding: (1) a *projection level* of organization which relates both the receptor and muscle events to the brain via "wire-in" neural mechanism; (2) an *integration level*, which organizes and sequences both incoming and outgoing neural events; and (3) a *representation* or *cognitive* level, which is at once the termination of decoding operations and the initiation of encoding operations. (p.77)

Turner and Poppel (1983) have examined in even greater detail the different time scales. "Events separated by periods of time shorter than three thousandths of a second are classified by the hearing system as simultaneous . . . If the sounds are a little more than .003 sec. apart, the subject will experience two sounds. However, he will not be able to tell which of the two sounds came first . . . When two sounds are about three hundredths of a second apart, a subject can experience sequence, accurately . . . Once the temporal interval is above three tenths of a second . . . [there] is enough time for a human subject to react to an acoustic stimulus." (p.294) The delayed auditory feedback experiments created maximum disturbance when the delay was approximately .25 seconds. This is approximately the time scale of the projection level in Osgood's model. The integration level on the other hand which must deal with sequences can operate ap-

proximately 10 times faster, and the representational level 100 times faster. On the other hand, it appears that in the actual operations, "A human speaker will pause for a few milliseconds every three seconds or so, and in that period decide on the precise syntax and lexicon of the next three seconds." (p.296) In other words, the prediction and ballistic units appear to be about 3 second intervals. Similarly, "A listener will absorb about three seconds of heard speech without pause or reflection, then stop listening briefly in order to integrate and make sense of what he has heard." (p.296) Through the use of a short term memory "buffer", the speech units are a) generated b) monitored, and regenerated and remonitored if necessary in order to make sense out of what was said.

Those who criticize the delay of oral response approach do not seem to understand that with appropriate listening guidance, both semantic and syntactic rules could be learned. Listening exercises can be created which focus on syntactical structure, just as listening tests have been created to test for comprehension of Broca's aphasic patients. "Broca's aphasics understand a sentence primarily by inferring what makes factual sense from a sampling of the major lexical items of the sentence-its nouns and verbs-independent of syntactic structure. When they can not make use of semantic and pragmatic cues their comprehension fails." (Zurif, 1980, p.307) Listening exercises can be created which develop a predictive capacity for both semantic and syntactic aspects of language. Oller (1972) has referred to this latter capacity as "grammar of expectancy".

The issue is not whether some people might not learn the syntactic rules by just listening, but determining how to create listening exercises which do in fact do just that. We know for example that grammatical features of speech are more informative and distinguishable when the semantic references for the utterances are present than when they are absent. Young children, for example, are aided in comprehending plural forms if they hear singular and plural labels applied to single and multiple objects repectively. The acquisition of syntactic language rules is greatly facilated

by pairing linguistic modeling with perceptural references. This has been confirmed by Brown (1976) in an experimental study.

This has also been the kind of listening practice advocated by those such as James Asher (1969), who has strongly promoted the use of the Total Physical Response Strategy. The same kind of listening practice has been advocated by most of those who promote the delay of oral response. Advocates of authentic listening on the other hand, tend to ignore this use of perceptual referents for syntactical differentiation. Many listening exercises for adult second language learning also ignore this point. Many of these listening exercises tend to involve the "general meaning" of the passage. The consequence is that they do not necessarily learn the syntactic rules and hence transfer to speaking is neither automatic nor complete. The prediction principle to be useful must be understood more completely. The cybernetic approach points out that if the feedback concept is to hold for both the syntactic prediction aspect as well as the semantic predication aspect, then both must be developed through carefully developed listening exercises.

Summary

400 years ago, Copernicus helped change the world by proposing that astronomers change their viewpoint. 40 years ago, Wiener suggested an alternative way of looking at human behavior. Copernicus did not change reality, he only helped us change our viewpoint of it. But that change of viewpoint lead to modern physics, modern science and our modern world. Cybernetic feedback theory has created a "scientific revolution" in the philosophy of science. It has reintroduced the concept of a final cause or teleology as a legitimate scientific explanation. It has not changed reality, only our viewpoint of it. This is creating ripple effects in a number of scientific disciplines. Specifically, it is reintroducing the concept of purpose in human behavior as a legitimate concept. It does this by integrating time in a behavioral act through the concept of feedback. This shifts the determinism of behavior from the environment to the individual.

Basically cybernetic feedback theory sees the individual as a self-organizing feedback control system which generates its own activity in order to control its own percep-

tions. In terms of motor activities, this means that the individual has its own perceptual mappings which are used to guide the activities of the individual through a feedback testing of the perceptual realities with the perceptual mappings already existing in the brain. Applying the principle of feedback to language usage, we discover that speaking as an overt public behavior is controlled by an *a priori* internally private listening capacity. With listening capacity, the transfer to the public performance of speaking, though not automatic is highly enhanced. Without that listening capacity, spontaneous speech, internally generated does not occur.

The practical effects of shifting one's viewpoint to the cybernetic feedback position are significant. In the prior position, which focused upon behavior as an indicator of learning, the teacher must *push* the student to perform publicly. The student's behavior is controlled by the teacher's control of the environment. This approach emphasizes speaking by the student so that the teacher can judge the students learning progress. The teacher then provides the student with the feedback of whether his speech was correct or not. The teacher is the judge of good speaking, not the student.

The new viewpoint sees the internal language structure *pulling* out the performance based upon built-in expectancies within the language structure learned through listening guidance. This is done by the student when he feels ready. The student is in control of his own behavior. The student like a rope is more easily pulled, than pushed. Since the speech is controlled by listening feedback, the student is the best judge of his own speech. From the teachers point of view, consistent errors indicated in spontaneous speech indicate weaknesses in the listening capacity. The errors of speech are thus not corrected directly, but noted for further training in careful listening. In other words, if a teacher accepts the second position, that all performances are perceptually controlled, then all learning is perceptual learning, and the task of the teacher is to enhance the student's perceptual capacity.

The viewpoint is new. It is not yet, "common sense". Nevertheless, it seems that cybernetic feedback theory has great potential for the future in foreign language teaching as well as in the various scientific disciplines. It seems premature to dismiss it as another fad, it seems more advisable to understand it better. This paper was presented in the belief that this new point of view could indeed create a "Copernican Revolution" in foreign language teaching.

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